U. S. ARMY
TRANSPORTATION RESEARCH COMMAND
FORT EUSTIS, VIRGINIA

TREC TECHNICAL REPORT 61-40

NOX

FLIGHT TEST EVALUATION OF AN IMPROVED EXTERNAL CARGO SLING SYSTEM FOR H-34 HELICOPTERS

Project 9R89-02-015-14

Contract DA 44-177-TC-587

March 1961

prepared by :

VERTOL DIVISION
BOEING AIRPLANE COMPANY
Morton, Pennsylvania

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January 1961

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Report No. R-237

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For

U.S. ARMY TRANSPORTATION RESEARCH COMMAND

FORT EUSTIS, VIRGINIA

FOREWORD

This report was prepared by Vertol Division - Boeing Airplane Company under Phase II of United States Army Contract Number DA 44-177-TC-587. Phase I was reported on by R-186, Project No. 9R38-01-017-52, dated March 1960. The project was originated by the U. S. Army Transportation Research Command, Fort Eustis, Virginia. Mr. Robert Powell, Project Engineer, and Mr. Ralph Aiken, Assistant Project Engineer, were cognizant TRECOM personnel in administrating the contract.

The project was conducted through the period of March 1960 to February 1961.

The following Vertol Division - Boeing personnel contributed to the preparation of this report:

Mr. K. Waters, Project Engineer
Mr. D. Howard, Design Engineer
Mr. A. Temple, Test Pilot
Mr. H. Steinmann, Flight Test Engineer

CONTENTS

SUMMARY

A test configuration of an improved external cargo sling for a single rotor helicopter herein called "cargo swing" has been designed, manufactured, and flight tested on an H-34 by Vertol Division, Boeing Airplane Company. Pilot comments indicated that, when carrying various loads, the swing resulted in a substantial improvement in aircraft handling characteristics as compared to the standard sling configuration. The pilot effort required to control the helicopter when using the swing was considerably less than that required under identical conditions with the standard cargo sling.

The cargo swing was designed to locate the effective point of suspension of externally carried cargo nearer the aircraft center of gravity, ref. figure 7. The effective point of cargo suspension, with the cargo swing, varies from 16.3 to 30.5 inches below the normal c.g. of the H-34 helicopter depending on the angle of swing (longitudinal or lateral) of the cargo with respect to the aircraft. The effective point of cargo suspension of the standard sling lies at 120 inches below the normal c.g. of the H-34 helicopter. By using the swing concept, coupling is reduced between lateral and longitudinal motion of the cargo and rolling and pitching motion, respectively, of the helicopter.

The cargo swing was evaluated in comparison to the standard cargo sling on the H-34. The program involved flying under stabilized flight conditions with the following cargoes: H-21 blade box, Army Conex box, and a 3200-pound high density load (concrete filled pipes). Various cable lengths between the cargo and hook were used. All flights were made by the same pilot and under wind conditions of less than 25 knots.

In addition to the stabilized runs noted above, stabilized V_{max} runs of 60 knots with a Conex box were made utilizing the swing system. V_{max} runs of 30 knots were deemed the limit of safe operation for this load with the standard cargo sling. A right coordinated turn at 30 knots and lateral flight were also performed with both the cargo swing and cargo sling with the 3200-pound high density load. Oscillograph instrumentation records of pitch rate, roll rate, roll attitude, longitudinal and lateral stick position, and airspeed were taken for all of the above flight conditions on both the cargo sling and cargo swing.

The external cargo swing configuration for single rotor helicopter that is discussed and shown in the following pages is not to be considered as a prototype. Further development could result in lighter weight and a method of retraction where internal cargo space would not be affected. The purpose of this test program was to prove the double axis cargo swing concept feasible for single rotor helicopters as well as to determine whether further development is warranted.

CONCLUSIONS

Based on the flight tests the following conclusions were reached:

1. Helicopter stability with low density external cargo (i.e., empty Conex box and helicopter blade box) suspended on the cargo swing was greatly improved over stability obtained with the standard H-34 sling. The high density 3200-pound load presented no stability problem with either the standard sling or swing. Instrumentated data records showed only slight or no improvement in aircraft performance under all test conditions; however, pilot comments rated the swing as vastly superior to the standard sling. A typical data recording elapsed time was 4 seconds, and this short time span may not reflect a comprehensive evaluation of the overall flight conditions.

2. Swing extension and retraction was satisfactory for this evaluation, but improvements would be required for a production model swing (see Recommendations).

3. The electrical load release system was satisfactory in all respects. Manual release of cargo from the swing was satisfactory from the cargo compartment, but operation of the pilot's foot emergency release was non-functional throughout the testing. This foot release requires a travel of approximately three inches and an estimated force of about 200 pounds to effect a successful load release. The high force required to release cargo by actuation of the pilot's foot pedal is due to the short stroke of the pedal and friction in the flexible enclosed-cable system. The short stroke is further reduced by lost motion which is inherent in flexible systems of this type. Modification of the pilot's manual release system when using the cargo swing is essential to safe transportation of external load. An electrical failure would prevent electrical release of the cargo and simultaneously eliminate electrical communications between the pilot and cargo operator. In an emergency, verbal communications between the pilot and cargo operator would then be required and the decision to jettison load might fall heavily on the judgment of the crewman.

4. The swing installation that was tested necessitates an open hatch in the cargo compartment floor for swing retraction (see recommendations for redesign improvement). The swing can be easily stowed in the cargo compartment by disconnecting the 340-1 cables at the fuselage attach fittings and retracting the entire assembly into the cargo compartment. With the swing thusly stowed, a hatch cover can be installed over the hatch to reduce exhaust fume contamination of the cargo compartment. The helicopter must land to reinstall the swing from this stowed position.

5. The results of this test program were consistant with the improvements obtained in test programs as described in Vertol Reports R-177 and R-232, covering testing of an improved cargo swing on the H-21 helicopter. These improvements are: reduced pilot effort; ability to take off with load off center; and ability to fly at higher Vmax because of no limitations in controllability of the helicopter. Pilots report that handling characteristics of the helicopter with an external load suspended from the cargo swing are "quite similar to those with internal cargo".

RECOMMENDATIONS

The following improvements are recommended for a production model swing.

1. It is recommended that the existing retraction system be modified. One modification could consist of retracting the swing far enough into the hatch to provide minimum ground clearance for the hook. A floor mounted enclosure approximately 19 inches high and 13 inches in diameter would contain the apex of the retracted swing and a hand operated or power winch would be used for retraction and extension of the swing. Cables shown extended in Figure 2 could also be made to retract inside. Another design modification could be one to retract the swing against the bottom of the helicopter entirely on the outside (Ref. Report R-232).

2. For safe transportation of external cargo with the cargo swing, the pilot's emergency release system should be modified to provide for greater stroke which will lower the force required. Selection of a system which involves low friction and a minimum of lost motion is highly desirable.

INTRODUCTION

This report describes a flight test evaluation of an improved external cargo sling designed for and tested on the H-34 helicopter under Contract DA-44-177-TC-587. The cargo sling for single rotor helicopters is a double axis swing designed to reduce the rolling and pitching moments imposed on the H-34 helicopter by externally slung loads. The sling accomplishes improved stability by locating the effective point of suspension of the cargo closer to the aircraft's center of gravity.

A double axis swing was considered necessary for the H-34 helicopter because maximum improvement was desired in both pitch and roll axis which would make the improvement equivalent to that achieved on the H-21 single axis swing. The H-21 swing has the longitudinal axis pivot point at the fuselage attachment which was completely adequate from a pitch control standpoint. The H-21 and the H-34 tests were part of a continuing development program aimed at improving transport of external loads by helicopter.

INTRODUCTION

This report describes a flight test evaluation of an improved external cargo sling designed for and tested on the H-34 helicopter under Contract DA-44-177-TC-587. The cargo sling for single rotor helicopters is a double axis swing designed to reduce the rolling and pitching moments imposed on the H-34 helicopter by externally slung loads. The sling accomplishes improved stability by locating the effective point of suspension of the cargo closer to the aircraft's center of gravity.

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DISCUSSION

Discussion of Data

Description of External Cargo Swing System

The cargo swing was designed with cable supports to permit freedom of movement in all directions (Ref. Figs. 1, 2, 3). A swivel was incorporated above the hook to eliminate need for a cargo anti-rotation device. The swing installation was designed for a 5000 pound load with a 2.67 limit load factor, or 13,350 pound limit load. Proof loads to 7500 pounds were imposed on the cargo swing and fuselage attachment fittings prior to flight test with no evidence of yielding or failures. The design load can be applied at angles up to 30° from the vertical in any direction. See Appendix I for the stress analysis of the system.

The cargo swing as used in this test had a weight of 62 pounds, excluding the cargo hook. The cargo swing utilized the existing H-34 cargo hook (Federal stock no. SN-4519-1680-SP-4070-3(FIA 110).

Normal release of the cargo hook was effected electrically by the pilot's cyclic stick thumb button. A manual emergency release utilized an independent passive hydraulic system tied to the existing pilot foot control used for release of the standard H-34 cargo hook. A crew chief emergency release handle was located in the cargo compartment and is used to actuate the same hydraulic system for manual release.

Modifications to the basic helicopter for this cargo swing test installation included; installation of new fuselage attachment fittings utilizing the existing bolt pattern; installing a hydraulic pump in the hatch which connected to the existing foot pedal release system as well as a manual release for the crew in the cabin; and a rope and pulley retracting system which can pull the collapsed swing assembly part way into the cabin. All other modifications were temporary and involved the flight test instrumentation only.

Proof Load

A proof load test was conducted before flight tests to determine that the cargo swing would meet the carrying capacity requirement of 1.5 times the 5000 pound design load. The helicopter H-34C S/N 57-1686 was placed over the external cargo sling test pit at Vertol and a test setup made to proof load the cargo swing (Ref. Fig. 4 & 5). An SR-4 load cell was placed between the hydraulic loading ram and cargo hook to give accurate readings of the various loads. The weight of the helicopter was taken off the main landing gear by two hydraulic jacks placed at jack points on each side of the fuselage nose. The wheels were raised approximately six inches above the hangar floor to allow travel of the ram used to apply load to the cargo swing. Proof load tests indicated that the cargo swing would carry 7500 pounds at an angle of 26 degrees with the vertical in the forward, aft, and lateral direction. The angle of 26 degrees was the maximum obtainable with the H-34 located over Vertol's external cargo sling proof load pit. The

DISCUSSION

Proof Load (continued)

7500 pound load applied at angles of 26^{o} is completely adequate for proof load of the cargo swing installation even though the swing was designed for higher loads. The main concern during proof load was the fuselage fitting installation since it was desired to pick up existing fitting mounting holes thus reducing the fuselage modification to a minimum.

After the proof load was completed a reanalysis of the fittings indicated that the fuselage fittings as originally designed were of marginal strength. Therefore, in the interest of good design practice a new set of fittings was designed and fabricated for the flight tests. Since these new fittings were similar to the originally designed fittings except for a substantial increase in material thickness, it was decided that a repeat of the proof loading was unnecessary.

The emergency manual hook release operated without hesitation upon application of 76 inch-pounds torque to the manual emergency release on the remote control unit for all test loads up to 5000 lb. No load releases were attempted above the 5000 lb. design load. Refer to Appendix I for Stress Analysis of Cargo Swing.

FLIGHT TEST PROGRAM

Flight testing of the cargo swing consisted of four flight categories: pilot checkout and familiarization, instrumentation check flight, standard sling evaluation, and cargo swing evaluation (total flight time 11:37 hours). Flights in ground effect were conducted to evaluate swing extension and retraction, electrical and mechanical load release, and load stability during flight maneuvers. (Refer to figure 6 for outline of flight test program).

Test instrumentation was installed in the helicopter. Selected data and time histories were analyzed.

The following data items were measured and recorded during flight tests:

a. Recorded Versus Time:

cyclic stick position - longitudinal & lateral
pitch attitude
roll control
pitch rate
roll rate
(cargo swing only) cargo position vs. aircraft - longitudinal & lateral

b. Cockpit Indicators:

cyclic stick position - longitudinal & lateral
(cargo swing only) Load position, longitudinal & lateral

c. Standard Cockpit Instruments: OAT, MAP, Engine RPM, Attitude

d. Ground Observer Data:

atmospheric pressure
wind velocity and direction relative to aircraft

Photographic coverage was provided consisting of motion pictures of all flights with external cargo and still photographs of test installation on the ground and in flight.

Results of Tests

Pilot comments on the flight to compare the cargo swing with the standard H-34 cargo sling are included in Appendix II.

During the tests, it was obvious to the pilot and observers that the aircraft, when utilizing the cargo swing, exhibited substantially improved flying qualities and reduced pilot effort over that which existed using the standard cargo sling. When carrying a 1600 lb. Conex box, speeds up to 60 knots were obtained with the swing. When using the standard cargo sling a maximum speed of 30 knots with the same load (1600 lb. Conex box) was deemed the limit of safe flight by the pilot.

Selected time histories were analyzed for instrumented runs on both the standard sling and the cargo swing. The results were inconclusive for the runs selected.

Fig. 1 CARGO SWING EXTENDED

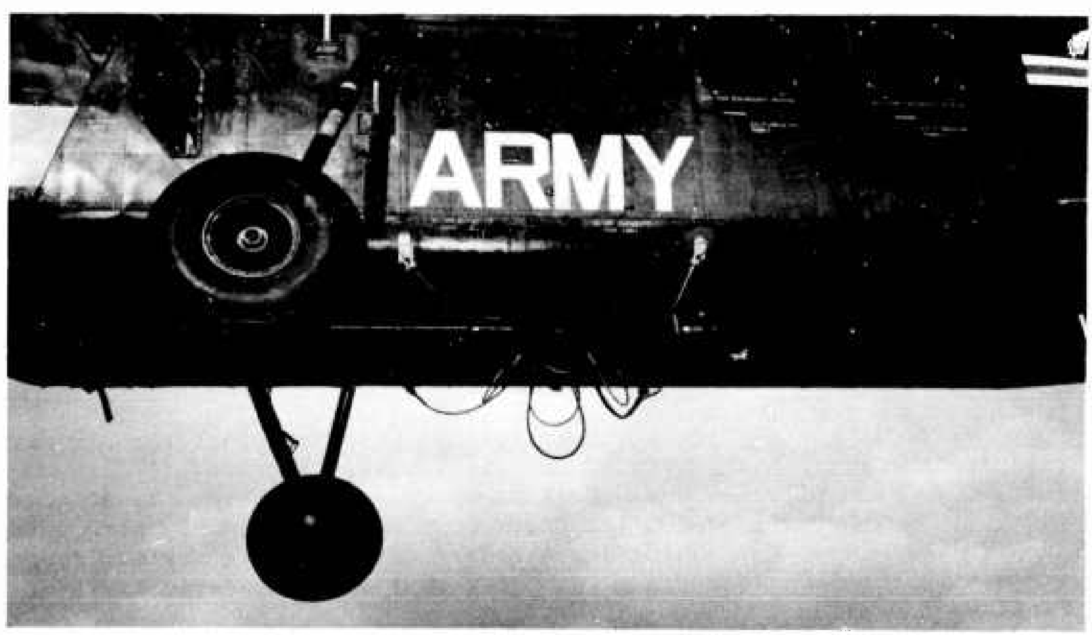


Fig. 2 CARGO SWING RETRACTED

Fig. 3 CARGO SWING -- HOVERING WITH 3200-POUND LOAD

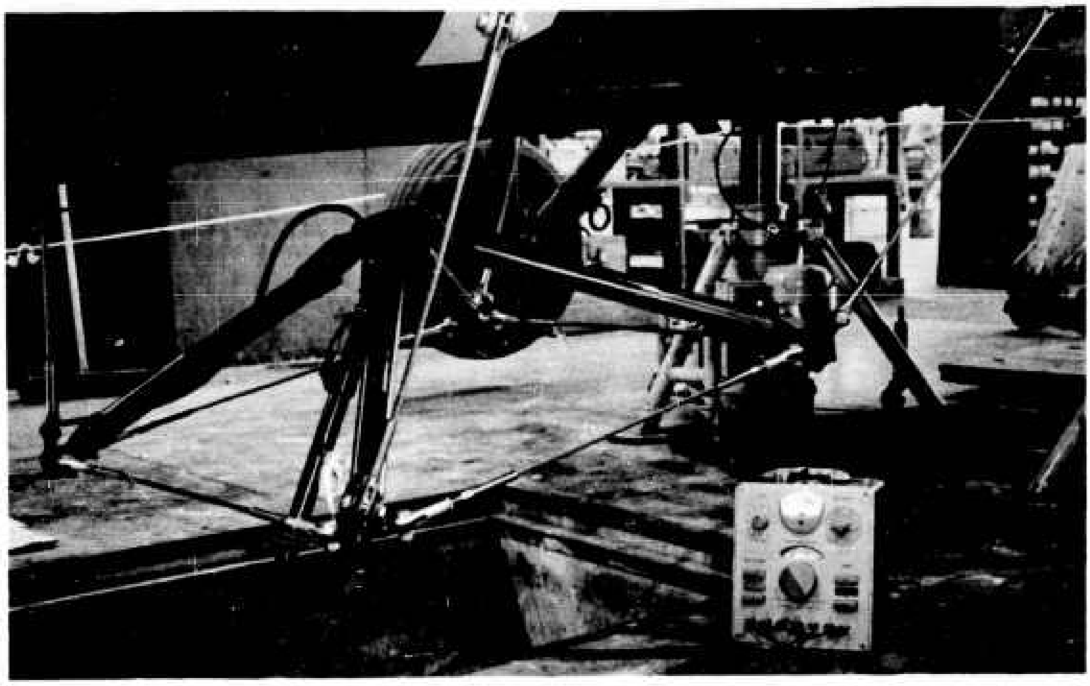


Fig. 4 SWING ASSEMBLY PROOF LOAD TEST SET-UP

Fig. 5 RELEASE HOOK PROOF LOAD TEST SET-UP

IMPROVED CARGO SYSTEM
H-34 FLIGHT TEST

Wind Conditions: Not Beyond Safe Maximum

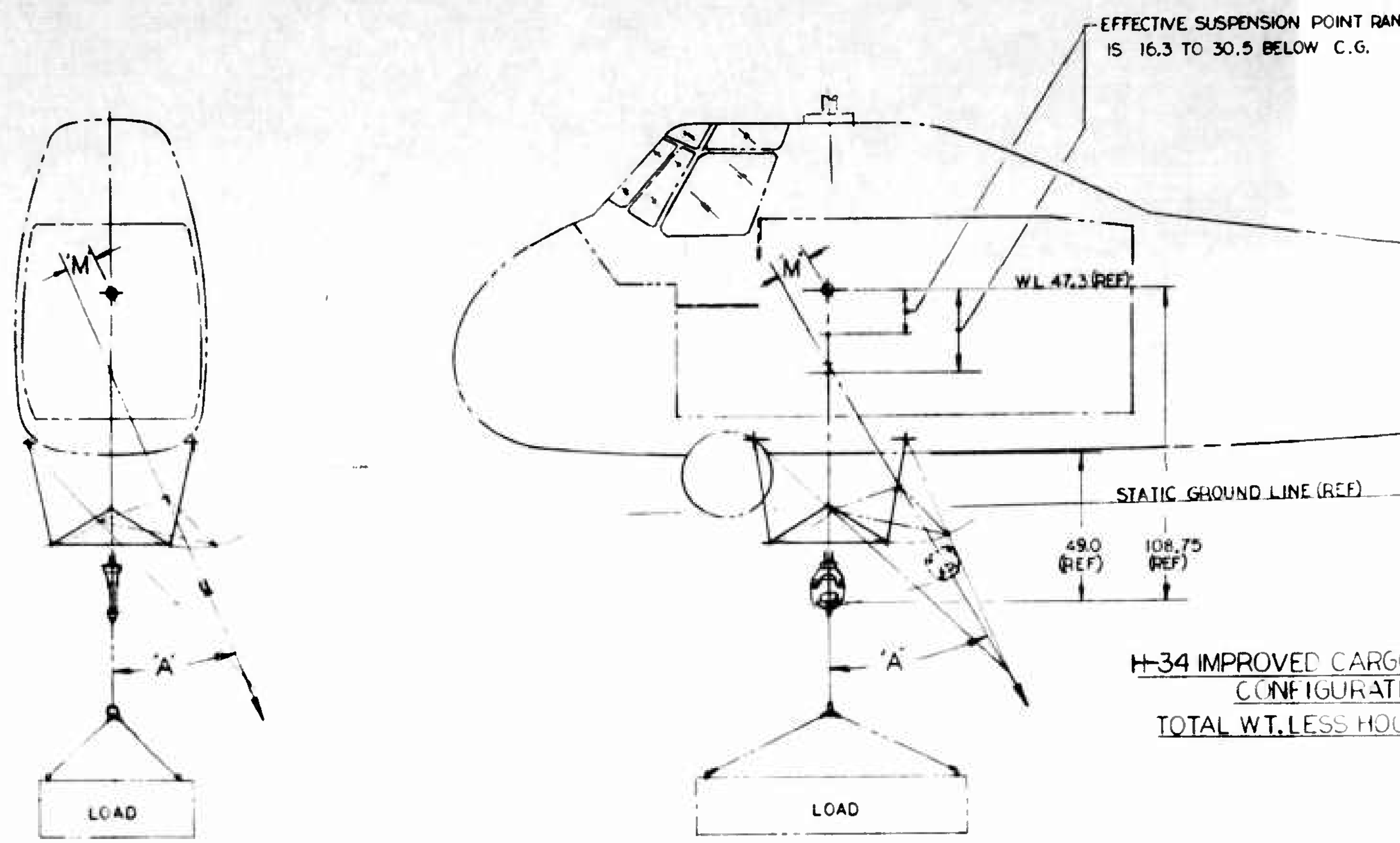
ITEM NO.	CONFIG. SWING	CONFIG. SLING	LOAD 3200	LOAD CONEX	LOAD BLADE BOX	CABLE LENGTH 0	CABLE LENGTH 10'	CABLE LENGTH 20'	MANEUVER* T	H	AR	AL	S30	S60	SV	ST	D	D30	Y	NU	SR
1.		X	X			X			X	X	X	X	X	X	X	X	X				
2.		X	X				X				X	X									
3.		X	X					X			X	X									
4.		X		X		X			X	X			X								
5.		X			X	X				X			X								
6.	X		X			X			X	X	X	X	X	X	X	X	X				
7.	X		X				X				X	X									
8.	X		X					X			X	X									
9.	X			X		X			X	X			X	X	X						
10.	X				X	X				X			X	X	X						
11.	X		X			X													X		
12.	X		X					X											X		
13.	X		X			X														X	
14.	X		X					X												X	
15.	X		X			X															X
16.	X		X					X													X
17.	X		X					X					X								
18.	X		X					X						X							
19.	X		X					X										X			

*MANEUVER CODE

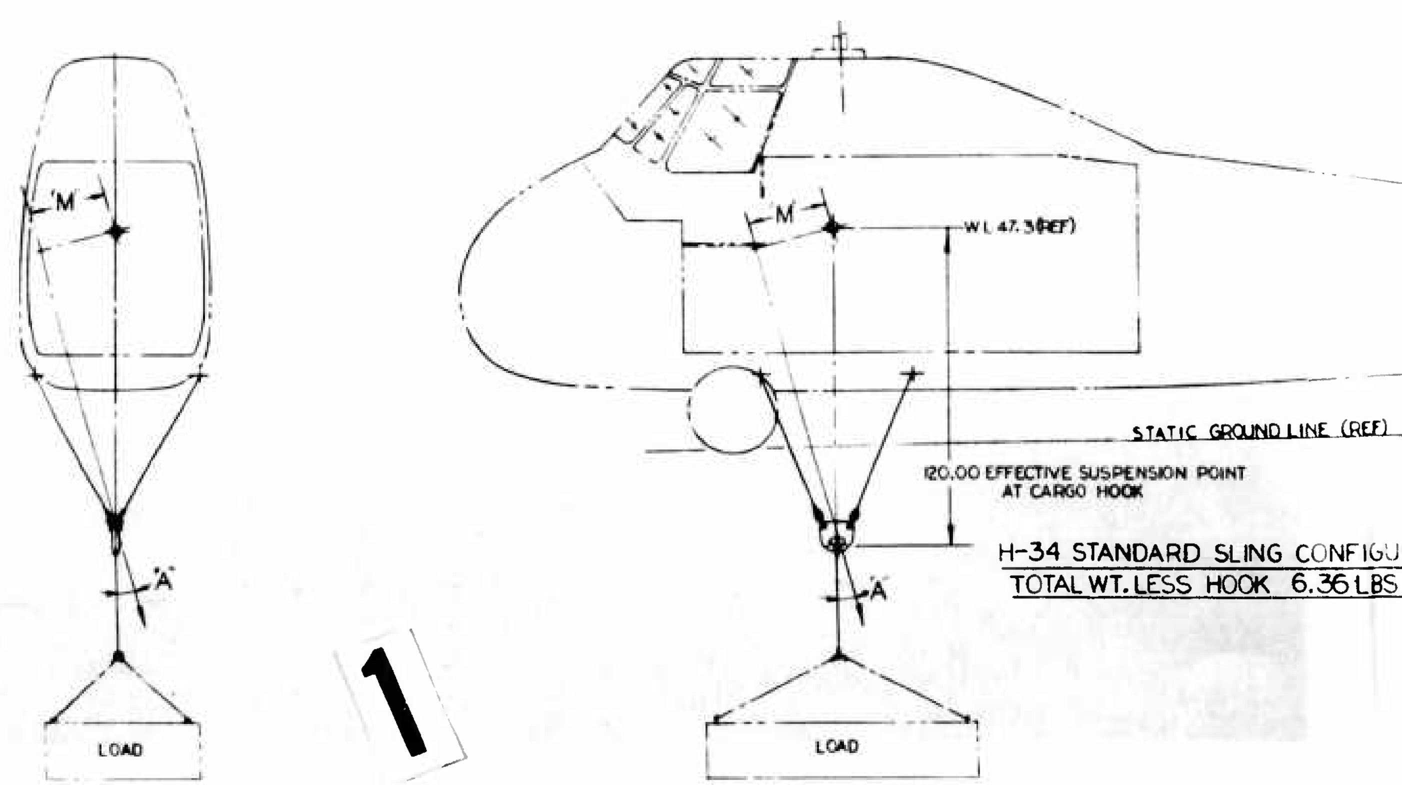
AL Accelerate to left from hover and recover to hover (stick impulse).
AR Accelerate to right from hover and recover to hover (stick impulse).
D Deposit load on ground (hook release check)
H Hover

S30 Steady state forward level flight at 30K IAS
S60 Steady state forward level flight at 60K
SV Steady state forward level flight at Vmax (NRP) (in field)
ST Sharp turn, coordinated, 90^{o} to right from steady state forward level flight at 30K
T Takeoff with load
Y Right and left yaw
NU Nose-up and nose-down pitch
SR Right and left stick raps
D30 Deceleration 30 knots I.A.S. to hover

Figure 6

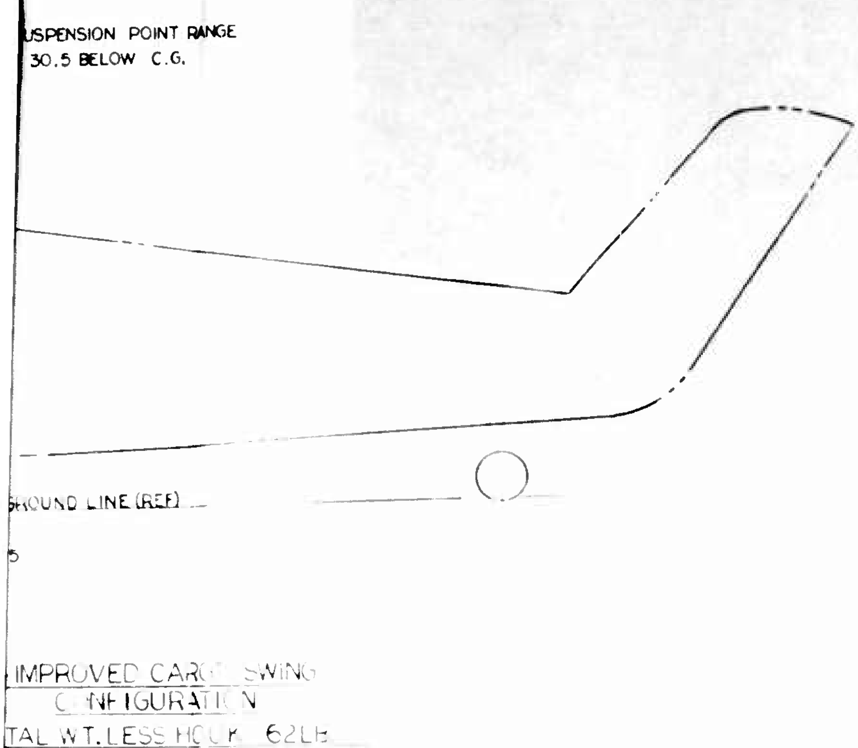


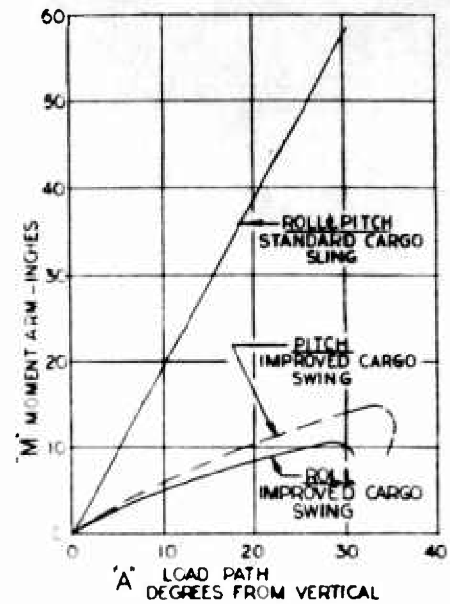
H-34 IMPROVED CARGO
CONFIGURATI
TOTAL WT. LESS HOO

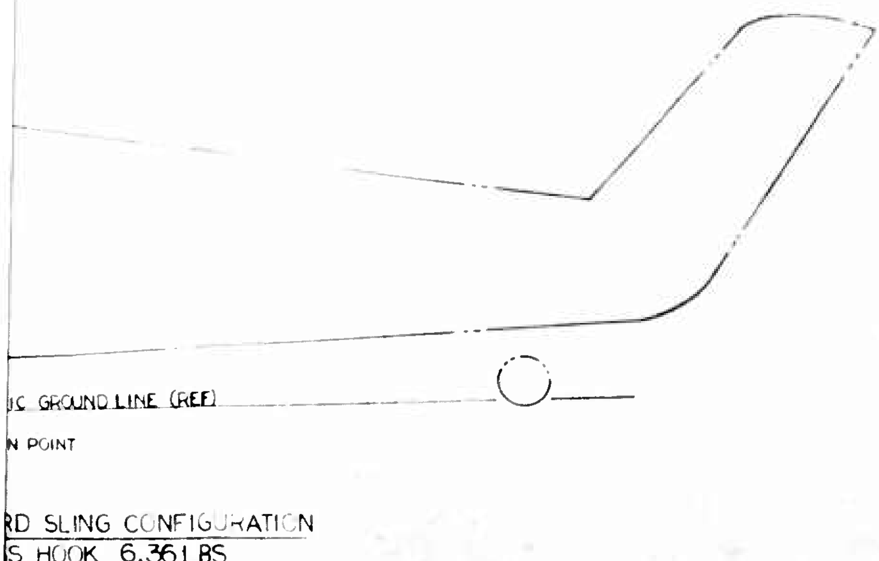


H-34 STANDARD SLING CONFIGUR
TOTAL WT. LESS HOOK 6.36 LBS

1







2

PRINT REDUCED
ONE - HALF
INDICATED SCALE

Fig. 7

DRAWN BY 1-13-61 JANDRIS	GROUP ENGR.	STRESS	PROJ. ENGR.	CUST.	COMPARISON STANDARD CARGO SLING VS IMPROVED CARGO SWING H-34	VERTOL MORTON, PENNSYLVANIA
CHECKED	WEIGHTS			F.A.A.	SCALE 1/2 — CODE IDENT. NO. 77272	DWG. SIZE - SK10293 — SHEET 1 OF 1

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Vertol Divison, Development of Improved Cargo Sling System Incorporating Load Stabilization, Report No. R-186, Vertol Division, Boeing Airplane Company, Morton, Pennsylvania, 1959.

Vertol Division, Flight Evaluation of Redesigned External Cargo Sling for H-21 Helicopter, Report No. R-232, Vertol Division, Boeing Airplane Company, Morton, Pennsylvania, 1961.

APPENDIX I

Stress Analysis of H-34 Cargo Swing

STRESS ANALYSIS OF H-34 CARGO SWING

VERTOL DIVISION

BOEING AIRPLANE COMPANY

CODE IDENT. NO. 77272

PREPARED BY		REPORT NO.	NO. OF PAGES
J. C. L. Bryant	J. C. L. Bryant	R-203	10
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W. B. Peck	W. B. Peck		
APPROVED BY		CONTRACT NO.	ITEM NO.
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APPROVED BY		DATE	
K. T. Waters	K. T. Waters	24 June 1960	

REVISIONS

DATE	PAGES AFFECTED	REMARKS
A 7/12/60	1 (Introduction)	Page no. changed to 1; note on symbols revised.
	1A (Gen.Configuration); ii	Page no. changed to 1; page added to define symbols.

FORM 1357C (3/60)

REVISIONS

DATE	PAGES AFFECTED	REMARKS
(Rev.B)		
2-1-61	1	Add Dwg. No. 351-1 & -2, and 352-1 & -2. Change 340-1 to 340-3.
	9	Delete calculations of Fuselage Ft. 337-1 & -2. Change 340-1 to 340-3
	Add pps. 10, 11, 12, 13 & 14	

REV

INTRODUCTION

In order to reduce the rolling and pitching moments imposed on the H-34 Helicopter by externally slung cargo, the subject double axis cargo swing (hereafter called "cargo swing") is proposed. The cargo swing is designed to locate the effective point of suspension of the cargo nearer the center of gravity of the helicopter. The effective point of suspension, when utilizing the swing, ranges from approximately 16.3 inches to 30.5 inches below the normal c.g. of the H-34 Helicopter depending on the angle of swing of the external cargo with respect to the helicopter. The effective point of suspension of the standard sling lies at approximately 120 inches below the normal c.g. of the H-34 Helicopter. By using the swing concept, coupling is reduced between lateral motion of the cargo and rolling motion of the helicopter; and longitudinal swing of the cargo and pitching motion of the helicopter.

CRITERIA

The ultimate load is assumed acting anywhere within a cone whose internal angle is 60° and whose apex is 30" below the c.g. The axis of this cone is normal to the aircraft water line plane and passes through the c.g.

Preliminary layouts and analysis have shown that the swing is stable in all positions both inside and outside of the above cone.

The design load shall be:

5000# cargo @ 2.67 g (limit)

or

5000 x 2.67 x 1.5 = 20,000# (ultimate)

All symbols and material properties are in accordance with MIL-HDBK-5 (March 1959) and Vertol Structural Design Manual as noted on Page ii.

REV 7/12/60 A

SYMBOLS

A	Area (*)
D, d, t, w	Lug Dimensions, as noted
F	Allowable stress (*)
f	Applied stress (*)
K	Concentration factor (*)
M	Bending Moment
P'	Allowable load (*)
R	Stress ratio (*), Reaction
V	Direct shear
τ	Torsional moment

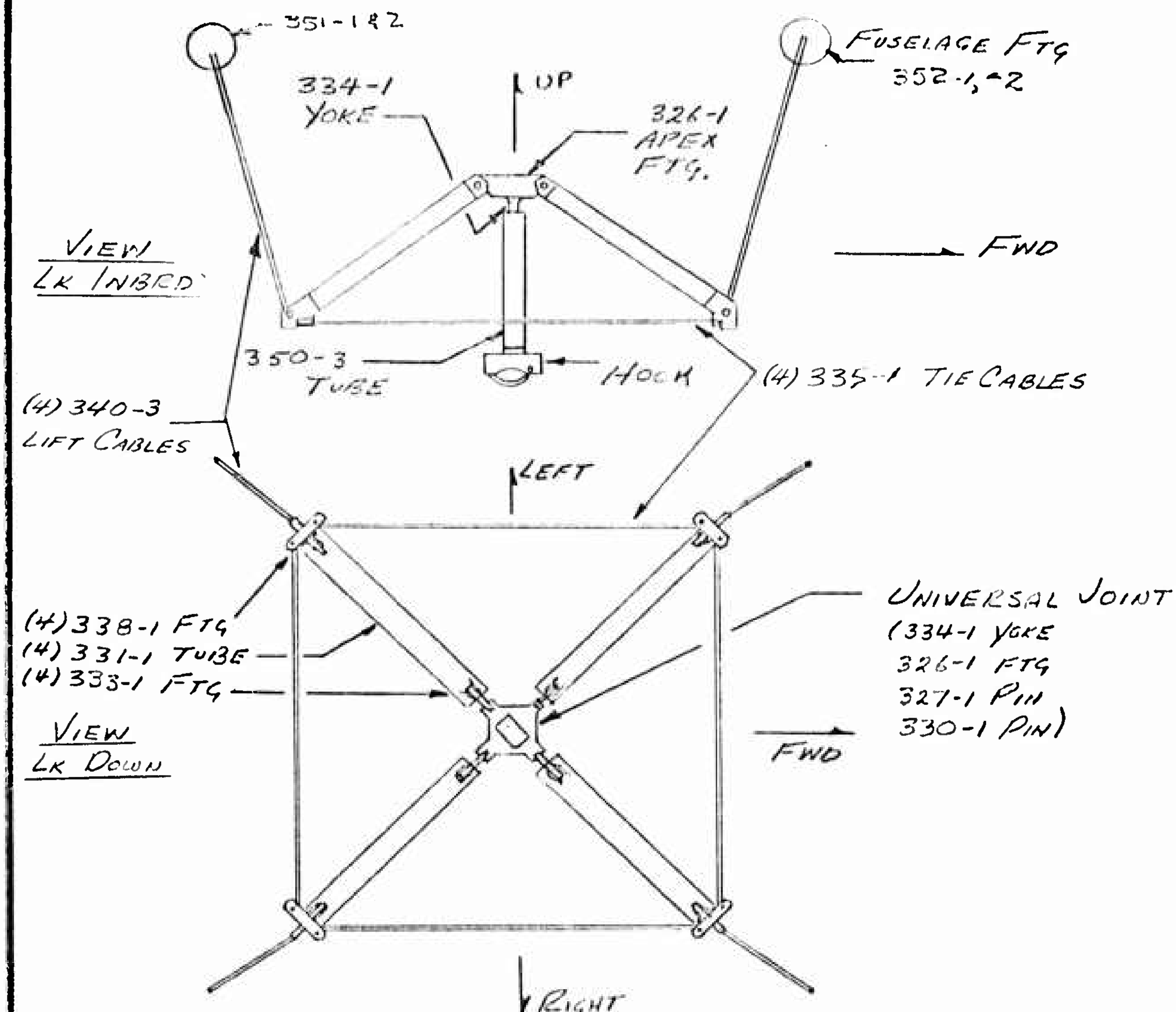
(*) Used with Subscript

Subscripts

ALL	Allowable
B, b	Bending
br	Bearing
c	Compression, Column
cr	Crippling
s	Shear
T, t	Tension
u	Ultimate
τ	Torsion

REV A 7/12

GENERAL CONFIGURATION



REF VERTOL DWG. 350

2/1/61 REV B

REF: VERTOL DWG. 350

HOOK

EASTERN ROTORCRAFT - MODEL A-60

TO BE SUBSTANTIATED BY PROOF TEST

ATTACHMENT OF HOOK TO 350-3 TUBE

$1\frac{1}{2} \times .25$ 6061-T6 TUBE

2 - AN5 BOLTS

SHEAR ALLOW. $= 4 \times 5750 = 23000^{\#}$

BRG ALLOW. $= 4 \times .25 \times \frac{5}{16} \times 1.5 \times 56^{KSI} = 26200^{\#}$

$$M.S. = \frac{23000}{20000} - 1 = \underline{\underline{+.15}}$$

TENSION IN 350-3 TUBE

$$A_T = \frac{\pi}{4}(\overline{1.5}^2 - \overline{1.0}^2) - 2 \times \frac{5}{16} \times .25 = .824^{IN^2}$$

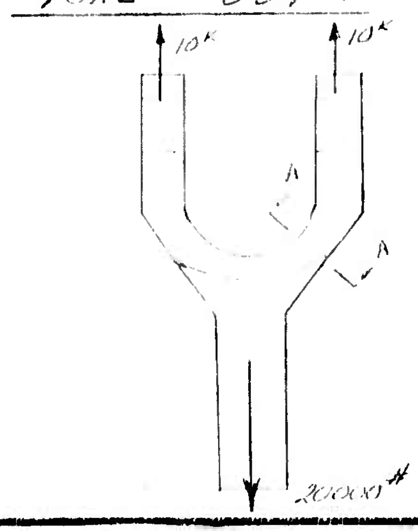
$$f_t = \frac{20000}{.824} = 24300^{PSI}$$

$UTS = 42^{KSI}$

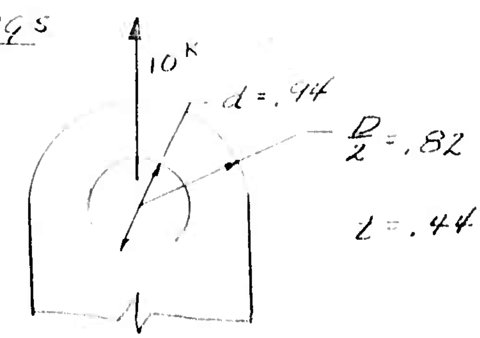
$$M.S. = \frac{42}{24.3} - 1 = \underline{\underline{+.73}}$$

YOKE 334-1

MTL: 2024-T4 (UTS $= 64^{KSI}$)



LUGS



$t = .44$

$\frac{D}{d} = 1.75 \qquad \frac{D/2}{d} = .875 \qquad \frac{d}{t} = 2.14$

REV

YOKE 334-1 (CON'T)

TENSION

$K_t = .79 \quad A_t = (1.64 - .94)(.44) = .308^{\text{IN}^2}$

$P_t' = .79 \times .308 \times 64^{KSI} = 15600^{\#}$

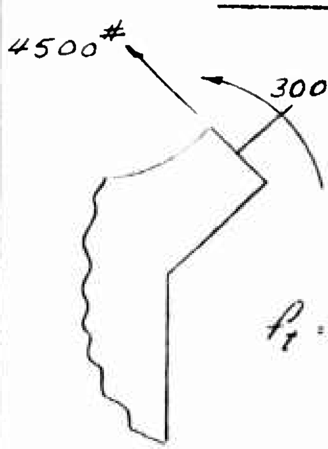
SHR-BRG

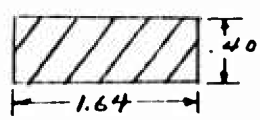
$K_{br} = .70 \quad A_{br} = .44 \times .94 = .414^{\text{IN}^2}$

$P_{br}' = .70 \times .414 \times 64^{KSI} = 18500^{\#}$

$M.S._{TENS} = \dfrac{15.6}{10} - 1 = \underline{\underline{+.56}}$

AT A-A





$f_t = \dfrac{6 \times 3000}{1.64 \times .4^2} + \dfrac{8500}{1.64 \times .40} = 68700 + 13000$

CONSIDER PLASTIC BENDING

$F_B = 1.5 \times 64 = 96^{KSI} \quad R_B = \dfrac{68700}{96000} = .715$

$F_T = 64^{KSI} \quad R_T = \dfrac{13000}{64000} = .203$

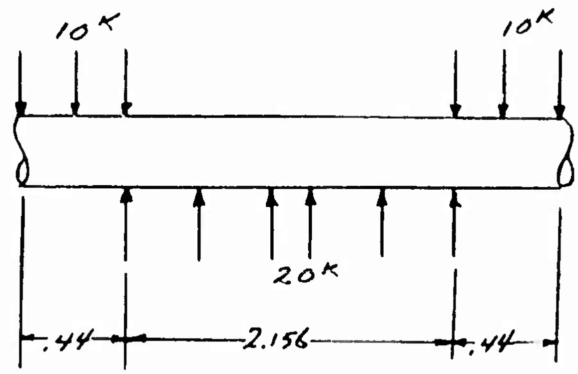
$R_B + R_T = .918$

$M.S. = \dfrac{1}{.918} - 1 = \underline{\underline{+.09}}$

PIN 327-1

M.F. MS 20392-10-103 8630 STL 125^{KSI} HT

PIN 327-1 (CON'T)



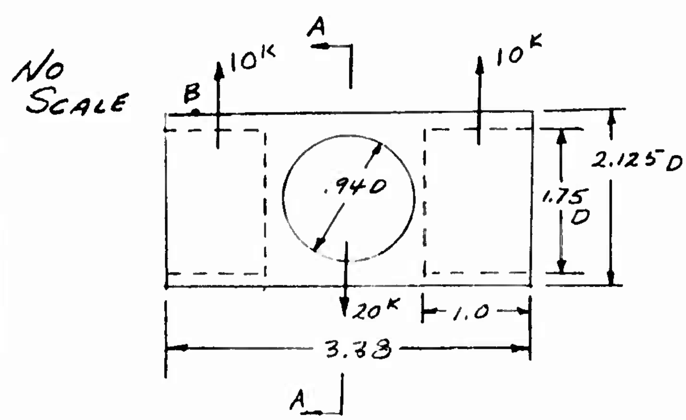
$$M_{MAX} = M_{\mathbb{C}} = (10^K)(1.298) - (10^K)(.54) = 7580''^{\#}$$

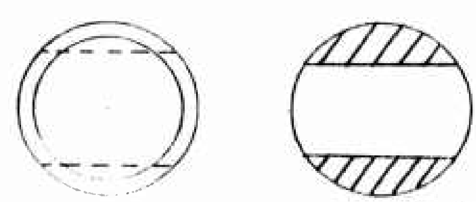
$$f_b = \frac{32M}{\pi d^3} \doteq \frac{32 \times 7580}{\pi\,(.75)^3} = 183000^{PSI}$$

$$F_b = 1.7 \times 125^{KSI} = 212^{KSI} \qquad M.S. = \frac{212}{183} - 1 = \underline{\underline{+.16}}$$

PIN ASSY 330-1

4130 STL UTS = 150^{KSI}





A-A

$$I = \frac{\pi(2.125)^4}{64} - \frac{1}{12}(2.1)(.94)^3 = .854\ IN^4$$

$$M_{\mathbb{C}} \cong 1.19 \times 10000 = 11900''^{\#} \text{ (CONSERVATIVE)}$$

$$f_b = \frac{11900 \times 1.06}{.854} = 14800^{PSI}$$

NOT CRITICAL

HOOP TENSION AT B

$$f_t = \frac{5000}{.188 \times .5^{*}} \times 2^{**} = 106000^{PSI} \qquad M.S. = \frac{150}{106} - 1 = \underline{\underline{+.41}}$$

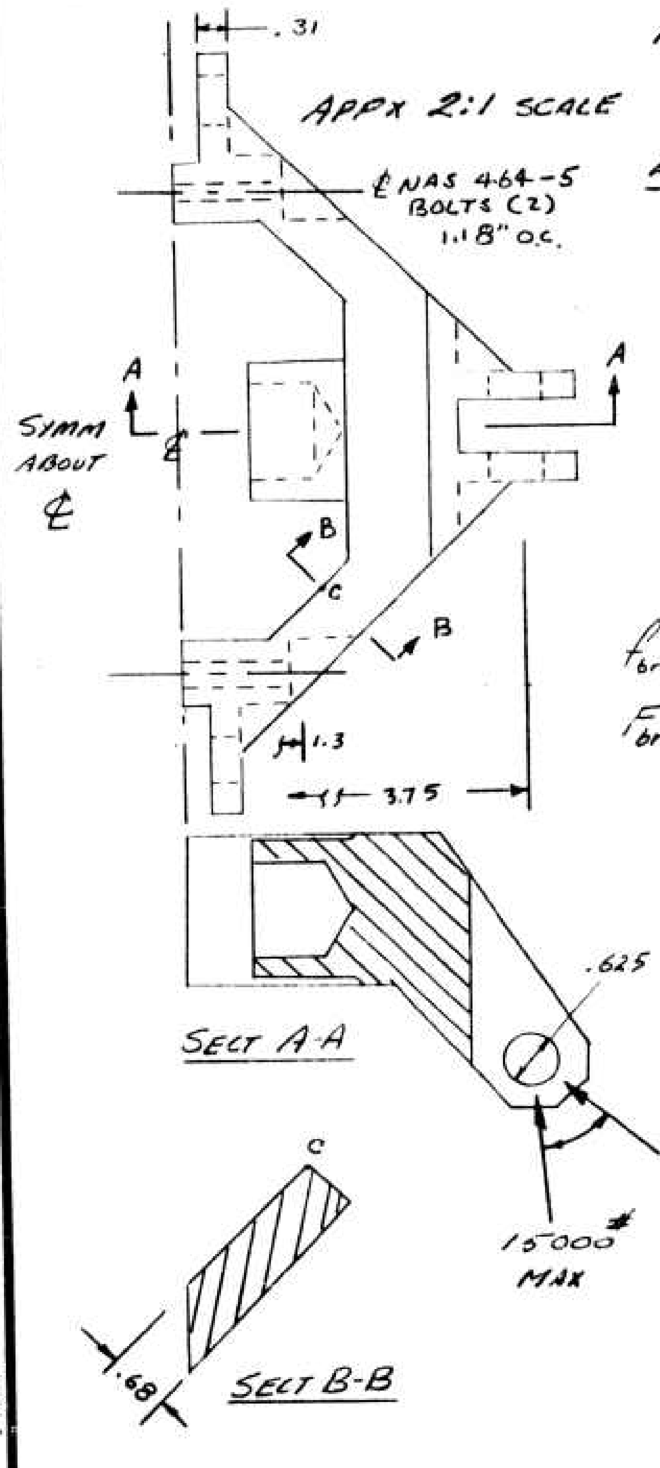
** ASSUMED CONC. FACTOR

* ASSUMED EFF. WIDTH

REV

APEX FTG. 326-1

MTL: 2014-T6 UTS=65 KSI



LUGS

ALWAYS SUBJECTED TO COMPRESSION LOADS AS SHOWN IN SECT A-A

∴ NOT CRITICAL IN TENSION OR SHEAR-BEARING BY INSPECTION

$f_{br} = \frac{7500}{.31 \times .625} = 38800$ PSI

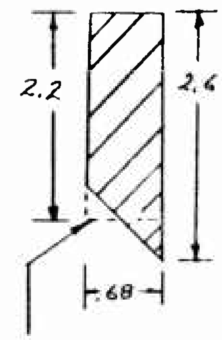
$F_{bru} = 98$ KSI

$M.S. = \frac{98}{38.8} - 1 = \underline{\underline{+1.53}}$

REV

APEX FTG 326-1 (CON'T)

SECT B-B



SHAPE ASSUMED FOR ANALYSIS

$$V = 7500^{\#}$$

$$T = 7500 \times .25 = 1875''^{\#}$$

$$M = 7500 \times 2.2 = 16500''^{\#}$$

$$f_b = \frac{6 \times 16500}{.68 \times 2.2^2} = 30,000 \text{ PSI}$$

$$f_{S_T} = \frac{1875\,(3 \times 1.1 + 1.8 \times .34)}{8 \times 1.1^2 \times .34^2} = 6500 \text{ PSI}$$

$$f_s = \frac{7500}{2.2 \times .68} = 5000 \text{ PSI}$$

$$\Sigma f_s = 11500 \text{ PSI}$$

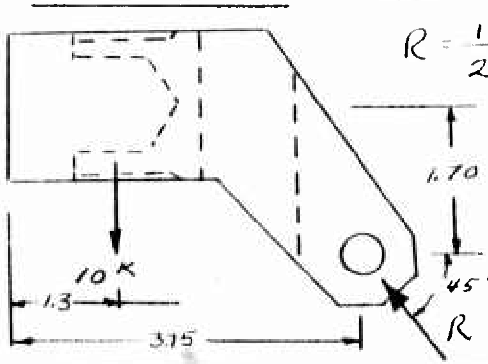
CONSERVATIVELY ASSUMING THAT $f_{s\,MAX}$ & $f_{b\,MAX}$ OCCUR AT THE SAME POINT:

$$R_b = \frac{30,000}{65,000} = .461$$

$$R_s = \frac{11500}{37000} = .312$$

$$M.S. = \frac{1}{.461 + .312} - 1 = \underline{\underline{+.78}}$$

CLAMP BOLTS (SYMM CONDITION)



$$R = \frac{10000}{2 \times .707} = 7080^{\#} \;;\; 7080 \sin 45° = 5000^{\#}$$

$$M = (10000)(1.3) + (5000)(1.70) - (5000)(3.75) = 2750''^{\#}$$

$$\text{BOLT TENS} = \frac{2750}{1.18 \times 2} = 1160^{\#}$$

$P_{ALL} = 6500^{\#}$ NOT CRITICAL

REV

TUBE 331-1

UPPER FTG 333-1 LUGS ALWAYS IN COMPRESSION

∴ TENSION & SHEAR-BRG NOT CRITICAL

$$f_{br} = \frac{15000}{.75 \times .5} = 40{,}000^{PSI} = 40^{KSI}$$

$$M.S. = \frac{61}{40} - 1 = \underline{\underline{+.52}}$$

APPX 8" OF 3/16 WELD

$$f_s = \frac{15000}{8 \times .188} = 10{,}000^{PSI} = 10^{KSI}$$

$$M.S. = \frac{24}{10} - 1 = \underline{\underline{+1.40}}$$

UPPER BOLT

AN-8 IN DOUBLE SHEAR

$$P_{ALL} = 2 \times 14700^{\#} = 29400^{\#}$$

$$M.S. = \frac{29400}{15000} - 1 = \underline{\underline{+.96}}$$

TUBE

$2\frac{1}{4} \times .033$ 6061-T6 ALUM ALLOY

$A = .565 \quad \rho = .767$

$$F_c = \frac{\pi^2 E \rho^2}{l^2} = 87000^{PSI}$$ NOT CRITICAL AS A COLUMN.

$$f_c = \frac{15000}{.565} = 26{,}600^{PSI}$$

$F_{CR} = 32000^{PSI}$
$(D/t = 27.1)$

$$M.S. = \frac{32000}{26600} - 1 = \underline{\underline{+.20}}$$

LWR FTG 333-1

BY COMPARISON WITH 333-1 (ABOVE)

OK BY INSPECTION

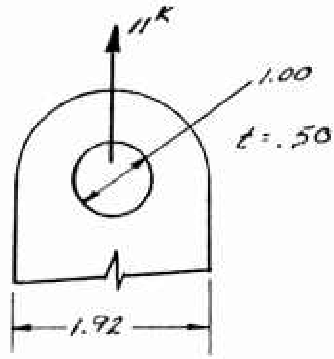
REV

LWR TUBE FTG 338-1 (CON'T)

332-3 PLATE (LIFT EYE) 6061-T6 $UTS = 42^{KSI}$

LIFT CABLE LOAD = 11000 #

SCHEMATIC



TENS:

$W/D = \frac{1.96}{1.0} = 1.96 \quad K_t = .72 \ (N)$

$P_{ALL} = .72 \times .50 \times .96 \times 42^{KSI} = 14.5^K$

SHR-BRG:

$a/D = \frac{.96}{1.0} = .96 \quad D/t = \frac{1.0}{.5} = 2$

$K_{br} = .80$

$P_{ALL} = .80 \times .50 \times 1.0 \times 42^{KSI} = 16.8^K$

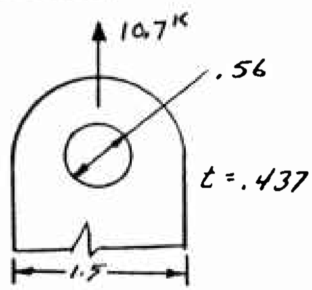
$M.S._{TENS} = \frac{14.5}{11} - 1 = \underline{\underline{+.32}}$

332-2 PLATE (TIE BAR)

MTL AS ABOVE

TIE CABLE LOAD = 10700#

SCHEMATIC



TENS:

$W/D = \frac{1.5}{.56} = 2.7 \quad K_t = .75 \ (L)$

$P_{ALL} = .75 \times .94 \times .437 \times 42^{KSI} = 12.9^K$

SHR-BRG:

$a/D = 1.35 \quad D/t = \frac{.56}{.437} = 1.28$

$K_{br} = 1.2$

$P_{ALL} = 1.2 \times .56 \times .437 \times 42^{KSI} = 12.3^K$

$M.S._{SHR\text{-}BRG} = \frac{12.3}{10.7} - 1 = \underline{\underline{+.14}}$

REV

TIE CABLES 335-1

3/8 d (7x19) MIL-C-5424 CABLE

$P_{ALL} = 12000^{\#}$

$$M.S. = \frac{12000}{10700} - 1 = \underline{\underline{+.12}}$$

LIFT CABLES 340-3

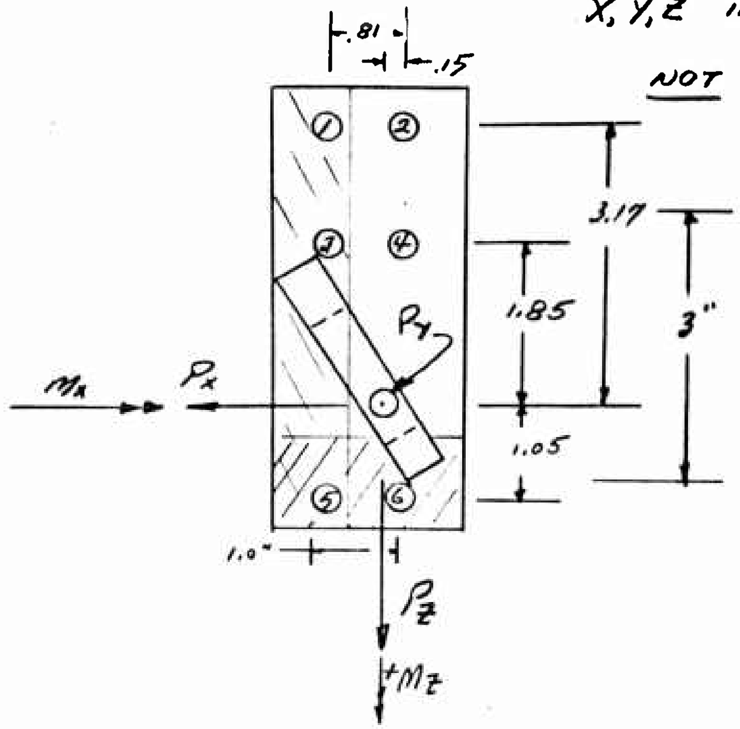
SAME AS ABOVE

$$M.S. = \frac{12000}{11000} - 1 = \underline{\underline{+.09}}$$

2-1-61
REV B

FWD FUSELAGE FTG 352-1 & 2

X, Y, Z IN FTG REF AXES SYSTEM NOT A/C REF.



P_X & P_Z ARE 1.0" OUT OF PLANE OF BOLT SHEAR REACTIONS.

$\pm P_X$ DIST ON SIX FASTENERS EQUALLY

P_Y 30% ON 5, 30% ON 6, 20% ON 3, 20% ON 4

P_Z SAME AS P_X

M_X REACTED AS A COUPLE, TENS ON 1 – 4, BRG ON /////

RESULTING TENSION LOAD; $\frac{1}{3}$ ON 3, $\frac{1}{3}$ ON 4, $\frac{1}{6}$ ON 1, $\frac{1}{6}$ ON 2

$+M_Z$ REACTED AS A COUPLE, TENS ON 2, 4, 6, BRG ON \\\\\

TENSION $\frac{1}{2}$ ON 4, $\frac{1}{4}$ ON 2, $\frac{1}{2}$ ON 6 (TOTAL 125%)

$-M_Z$ AS $+M_Z$ EXCEPT P_T $\frac{1}{4}$ ON 1, $\frac{1}{2}$ ON 3, $\frac{1}{4}$ ON 5

2-1-61 REV B

$P_X = 985$

$P_Y = 5440$

$P_Z = 5810$

$M_X = +5810$

$M_Z = +985$

$\underline{P_X}$ $\quad P_X = \frac{985}{6} = 164^{\#}$ ON 1 → 6

$\underline{P_Y}$ $\quad P_Y = 1630^{\#}$ ON 5 & 6 $\quad = 1090^{\#}$ ON 3 & 4

$\underline{P_Z}$ $\quad P_Z = \frac{5810}{6} = 970^{\#}$ ON 1 → 6

$\underline{M_X}$ $\quad P_T = P_{BRG} = \frac{5810}{3} = 1940^{\#}$

$P_Y = 646^{\#}$ ON 3 & 4 $\quad = 323^{\#}$ ON 1 & 2

$P_Y = -970$ ON 5 & 6

$\underline{M_Z}$ $\quad P_T = P_{BRG} = 985^{\#}$

$P_Y = 492^{\#}$ ON 4 & 6 $\quad = 246^{\#}$ ON 2

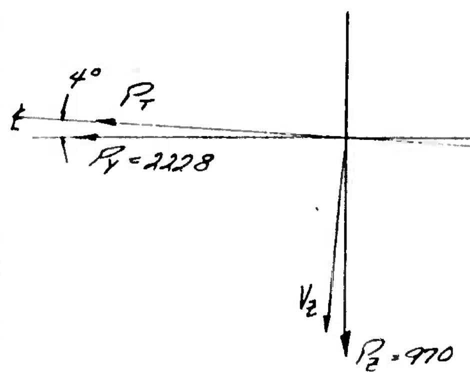
$P_Y = -492^{\#}$ ON 3 $\quad = -246^{\#}$ ON 1 & 5

BOLT	P_X	P_Z	P_Y
1	164	970	323 - 246 = 77
2	↑	↑	323 + 246 = 569
3			1090 + 646 - 492 = 1244
4			1090 + 646 + 492 = 2228 ← CRITICAL
5	↓	↓	1630 - 970 - 246 = 414
6	164	970	1630 - 970 + 492 = 1152

2-1-2
REV B

$$P_T = P_Y \cos 4^\circ - P_Z \sin 4^\circ$$

$$V_Z = P_Z \cos 4^\circ + P_Y \sin 4^\circ$$



$$P_T = 2150^{\#}$$

$$V_Z = 1120^{\#}$$

$$V_T = V_Z + P_X = 1130^{\#}$$

USE NAS 464-3

$$P_T' = 2830^{\#} \quad P_S' = 2690$$

$$R_T = \frac{2150}{2830} = .76$$

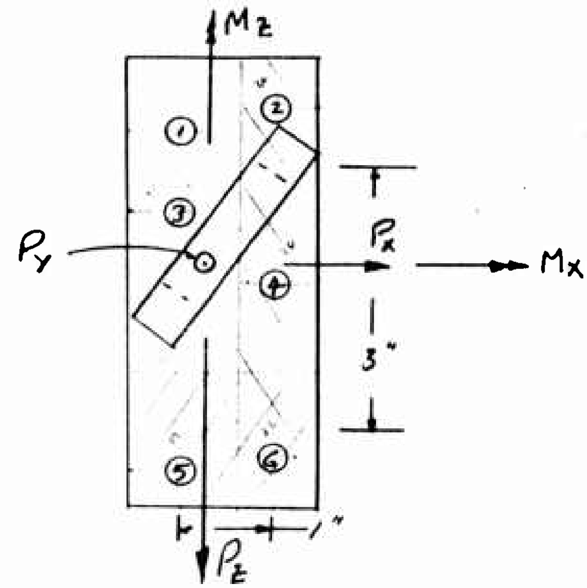
$$R_S = \frac{1130}{2690} = .419$$

$$R_T + R_S = .87$$

$$M.S. = \frac{1}{.87} - 1 = \underline{\underline{+.15}}$$

REV B 2-1-61

AFT. FUSELAGE FTG 351-14-2



P_x 1/6 TH PER

P_y 25% ON ② & ③ 20% ON ④ 12.5% on ⑤ & ⑥ & ① (107.5%)

P_z 1/6 TH PER

M_x BRG ON //// P_y 1/2 ON ② 1/3 ON ① 1/4 ON ③ (108%)

M_z BRG ON \\\\ P_y 1/2 ON ③ 1/3 @ ON ① & ⑤ (117%)

$P_x = 985$ $P_y = 5440$ $P_z = 5810$

$M_z = 985$ $M_x = 5810$

$\underline{P_x}$ $P_x = 985/6 = 164$ on ① → ⑥

$\underline{P_y}$ P_y: 1370 ON ② & ③ 1100 ON ④ 685 ON ①⑤⑥

$\underline{P_z}$ $P_z = 5810/6 = 970$ ① → ⑥

$\underline{M_x}$ $P_y = P_{BRG} = 5810/3 = 1940$; P_y 970 ② 645 ① 485 ③

P_y −970 ⑤ & ⑥

$\underline{M_z}$ P_y = 492 ③ 328 ①⑤ −492 ④ −246 ②⑥

REV B 2-1-61

Fwd

BOLT	P_x	P_z	P_y
1	164	970	685 + 328
2	↑	↑	1370 + 970 − 246
3			1370 + 485 + 492 = 2347
4			1100 − 492
5	↓	↓	685 − 970 + 328
6	164	970	685 − 970 − 246

$\Theta = 4°$

$P_T = 2347 \cos 4° - 970 \sin 4° = 2270$

$V_z = 970 \cos 4° + 2347 \sin 4° = 1130$

$V = 1130 + 164 = 1140$

$R_T = \dfrac{2270}{2830} = .803$

$R_S = \dfrac{1140}{2690} = .424$

$R_T + R_S = .906$

$M.S. = \dfrac{1}{.906} - 1 = \underline{\underline{+.10}}$

REV 2-1-61 B

APPENDIX II

PILOT'S COMMENTS

Enclosure (1)
EFM-2802

FLIGHT LOG
H-34C S/N 57-1686
CARGO SWING EVALUATION

Date	Flight No.	*G.W.	*C.G.	Flight Purpose (Remarks)
6/2/60	H-34-V1	-	-	Ferry - Ft. Fustis to Morton, Pa.
6/30/60	V2	-	-	Periodic inspection test flight.
7/25/60	V3	10,435	4.5"A	Pilot familiarization.
7/25/60	V4	10,335	4.4"A	" "
7/25/60	V5	9,810	2.6"F	" "
7/26/60	V6	9,526	3.2"F	" " with sling.
7/26/60	V7	"	"	" "
7/26/60	V8	10,435	4.5"A	" "
7/27/60	V9	9,935	1.9"A	Instrumentation check.
7/28/60	V10	9,726	3.2"F	Standard sling evaluation (instrumentation inoperative).
7/28/60	V11	9,526	3.2"F	" " " (engine power loss).
10/24/60	V12	10,251	5.5"A	Engine slow time.
10/25/60	V13	"	"	" " "
11/7/60	V14	10,651	5.3"A	Pilot refamiliarization.
11/9/60	V15	10,251	0.2"A	Instrumentation check.
11/9/60	V16	9,701	0.9"A	Standard sling evaluation (instrumentation malfunction).
11/11/60	V17	9,766	1.9"A	" " "
11/11/60	V18	9,526	3.2"F	" " " (instrumentation malfunction).
11/14/60	V19	"	"	" " " (" ").
11/14/60	V20	"	"	" " "
12/6/60	V21	9,782	2.1"F	Vertol swing and instrumentation check.
12/6/60	V22	"	"	Vertol swing evaluation.
12/7/60	V23	"	"	" " " (hook malfunction).
12/7/60	V24	9,607	2.9"F	Vertol swing evaluation (instrumentation malfunction).
12/8/60	V25	"	"	" " "

*Maximum T.O. Gross Weight: 13,300 lb.
Design Gross Weight: 11,867 lb.
C.G. Travel: 7" Forward to 9" Aft

PILOT COMMENTS

Flight No. H-34-V14 11/7/60

G.W.: 10,651 lb.
C.G.: 5.3"A

Purpose of Flight

Familiarization and instrumentation check.

Configuration

Standard cargo sling attached.

Changes Since Last Flight

None

Test Results

1. Instrumented records were taken during the following maneuvers: hover (IGE), right accelerations, left accelerations, coordinated right turn through 90° at 30 knots (IGE), and forward acceleration (in field) to Vmax and rapid acceleration to hover. The aircraft's handling characteristics were satisfactory to continue the program; however, rate gyros were inoperative.

A. H. Temple
Experimental Test Pilot

PILOT COMMENTS

Flight No. H-34-V15 11/9/60

G.W.: 10,251
C.G.: 0.2"A

Purpose of Flight

Instrumentation checkout

Configuration

Standard cargo sling attached.

Changes Since Last Flight

None

Test Results

1. Instrumented records were taken at Hd of 1900'. Records were recorded at 2300, 2500, and 2700 RPM at hover, 20, 40, 60, 85, and 100 knots. Aircraft handling characteristics and power required for various RPM settings at varying speeds were acceptable for test purposes.

2. Instrumented records and pilot's visual control movement indicators are satisfactory for evaluation of the cargo sling.

A. H. Temple
Experimental Test Pilot

PILOT COMMENTS

Flight No. H-34-V16 11/9/60

G. W.: 9,701 lb.
C.G.: 0.9"F
Wind: NW 11 knots

Purpose of Flight

Pilot evaluation of comparisons between standard external cargo sling and Vertol-designed external cargo swing sling.

Program

Standard cargo sling - load release check; carry 400 lb. weight; Conex box 1600 lb. using minimum riser (approximately 5').

Test Results

1. The 400 lb. weight was lifted and released twice to check hookup and releasing systems. While hovering with the 400 lb. weight, the longitudinal stick position was approximately 1 1/2" aft; lateral stick position stabilized at approximately 1" left. Mild accelerations were made to the left and right (approximately 10 knots). Forward flight to speeds of 30 knots was made, accompanied by banks of approximately 30° to the left and right. During decelerations, the vibration level increases appreciably and the load tends to swing, causing constant monitoring of lateral control.

2. The Conex box (1600 lb. weight) was lifted and carried to a forward flight speed of 30 knots. Entering and leaving the transition range, the vibration level increases appreciably over hover and stabilized flight conditions.

A. H. Temple
Experimental Test Pilot

PILOT COMMENTS

Flight No. H-34-V17 11/11/60

G.W.: 9766 lb.
C.G.: 1.9"F
Wind: N 7 gusty

Configuration

Standard external cargo sling; lift Conex box and blade box with minimum riser.

Changes Since Last Flight

None

Purpose of Flight

To evaluate handling characteristics between standard external cargo sling and Vertol-designed external cargo swing sling.

Test Results

1. The Conex box (1600 lbs.) was lifted and carried to a forward speed of 30 knots in the confines of the field. Instrumented records were taken during the pickup, hover, and forward speed regime. Handling characteristics were satisfactory during these maneuvers.

2. A metal rotor blade box was lifted and carried to a forward speed of 30 knots. Instrumented records were taken at hover and forward flight regimes. The handling characteristics were satisfactory during pickup and acceleration to 30 knots but became critical during deceleration, as the box had a tendency to swing excessively from side to side which required a maximum of concentration to maintain controllability.

A. H. Temple
Experimental Test Pilot

PILOT COMMENTS

Flight No. H-34-V18 — 11/11/60

G.W.: 9,526 lb.
C.G.: 3.2"F
Wind: W 3

Flight V19 - Instrumentation check.
Flight V20 - Repeat of V18.

Purpose of Flight

Pilot evaluation of comparisons between standard external cargo sling and Vertol-designed external cargo swing sling.

Program

Standard cargo-sling, lift 3200 lb. weight with minimum 10 and 20' riser cable, maneuver and evaluate.

Test Results

1. Instrumented records were taken on pickup, hover, right accelerations, left accelerations, forward flight to 80 knots in the field confines, and 30 knot coordinated turns with minimum riser cable. On accelerations to the right and left, speed was judged to be approximately 12 to 15 knots. Controllability was ample for these maneuvers.

2. With the 10' riser cable attached, the load was again lifted and accelerations to the right and left performed. Sideward speeds of approximately 10-12 knots were accomplished satisfactorily. The degree of controllability needed can be readily felt as the riser cable is increased.

3. With the 20' riser cable attached, the load was again lifted and accelerations performed to the right and left. Sideward flight speeds of approximately 8-10 knots were accomplished. The sideward flight speeds were limited by excessive load swinging tendencies with the 20' riser cable. At sideward flight speeds of five knots or less, controllability is ample.

A. H. Temple
Experimental Test Pilot

PILOT COMMENTS

Flight No. H-34-V22 12/6/60

G.W.: 9782 + 1600 + 250
C.G.: 2.1"F
Wind: SW 7

Purpose of Flight

Pilot evaluation of comparisons between standard external cargo sling and Vertol-designed external cargo swing sling.

Program

Vertol-designed swing sling: lift and carry Conex box, rotor blade box, and 3200 lb. weight with minimum riser cable. The following maneuvers are to be recorded: right acceleration, left acceleration, forward flight, right coordinated turns, pickup, and drop.

Comments

1. The Conex box (1600 lb.) was lifted and carried to a forward speed of 60 knots within the confines of the field. The load stabilized at 20° aft, and the maximum lateral swing was from zero degrees to ten degrees left. The overall handling qualities of the helicopter appear to be better with the swing sling installation.

2. The rotor blade box (250 lb.) was lifted and carried to a forward speed of 40 knots. The forward flight speed was limited due to excessive swaying along the longitudinal and lateral axes. The maximum longitudinal sway was 30° aft, while the lateral sway was from stop to stop. Comparing this to the standard sling results, both are comparable. The load (250 lb.) is very light and will sway excessively and dangerously if allowed to progress with either configuration.

3. Using a minimum length riser cable, a 3200 lb. weight was lifted and carried to a forward flight speed of 72 knots. The forward flight speed attained was limited only by local airport traffic and the restriction on operating within the confines of the field. The overall handling characteristics appear to be better with this installation than with the standard external sling. Coordinated turns at 30 knots and approximately 30° of bank required less concentrated effort on the part of the pilot with the swing installation as compared to the standard sling.

A. H. Temple
Experimental Test Pilot

PILOT COMMENTS

Flight No. H-34-V25 12/8/60

G.W.: 9607 lb.
C.G.: 2.9"F
Wind: NW 17, gusts to 22

Purpose of Flight

Pilot evaluation of comparisons between standard external cargo sling and Vertol-designed external cargo swing sling.

Program

Using the Vertol-designed swing sling, lift 3200 lb. weight with 0, 10, and 20' riser cable. Obtain records and comments on following maneuvers: right and left yaws, nose-up and nose-down pitch, right and left rolls, and forward flight.

Test Results

1. The above maneuvers were performed and instrumented records taken. This flight was a repeat of flight V24 for record purposes. The wind conditions were comparable on both flights. The overall controllability and handling characteristics were the same on both flights. As a comparison between the two installations, the Vertol-designed swing sling affords the pilot with more control authority and enables the load to remain closer to the centerline position while performing various maneuvers.

A. H. Temple
Experimental Test Pilot

PILOT COMMENTS

Flight No. H-34-V24 12/7/60

G.W.: 9607 - 3200
C.G.: 2.9"F
Wind: NNW 18, gusts to 25

Purpose of Flight

Pilot evaluation of comparisons between standard external cargo sling and Vertol-designed external cargo swing sling.

Program

Vertol-designed swing sling - lift 3200 lb. weight using 10' and 20' riser cable. Record and comment on right accelerations, left accelerations, yaws, and rolls.

Comments

1. Using a 10' riser cable, the 3200 lb. weight was lifted and accelerations to the right and left performed. Sideward flight speeds of approximately 15 knots were accomplished. Lateral control authority was satisfactory at all points. The maximum lateral sway attained was approximately 10^{o} either size of zero. Comparing the above maneuvers to the standard sling: faster rate of speed can be obtained with the swing sling installation, controllability is better, and the load has less swinging tendencies.

2. Using the 20' riser cable, the 3200 lb. weight was again lifted and the following maneuvers accomplished: right accelerations, left accelerations, right yaw, left yaw, and nose-down and nose-up pitch. Controllability was satisfactory on all maneuvers listed. Sideward flight speeds approximating 15 knots were accomplished satisfactorily. Comparing the two types of slings, the Vertol-designed swing sling allows for faster sideward flight speeds and enables the load to remain closer to the C.G. while maneuvering.

A. H. Temple
Experimental Test Pilot

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Vertol Report
"Improved Helicopter Sling Load Capability"

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Building 314, Room A-216 (1)
Fort Belvoir, Virginia

U. S. Army Transportation Research Command Liaison Officer
Airborne and Electronic Board (1)
Fort Bragg, North Carolina

Chief, Bureau of Naval Weapons (R-38)
Department of the Navy
ATTN: RA-4 (1)
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President
Marine Corps Equipment Board
Marine Corps Schools (1)
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Commandant
U. S. Army Transportation School
ATTN: Marine Corps Liaison Officer (1)
Fort Eustis, Virginia

Commandant
U. S. Coast Guard
ATTN: Chief, Testing and Development Division (1)
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Washington 25, D. C.

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National Aeronautics & Space Administration (1)
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Box 65, U. S. Navy 100 (1)
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Office of the Senior Standardization Representative
U. S. Army Standardization Group, Canada
c/o Director of Equipment Policy
Canadian Army Headquarters
Ottawa, Canada (1)

Canadian Army Liaison Officer
Liaison Group, Room 208
U. S. Army Transportation School
Fort Eustis, Virginia (3)

British Joint Services Mission (Army Staff)
ATTN: Lt. Col. R. J. Wade, RE (3)
DAQMG (Mov & Tn)
3100 Massachusetts Avenue, N. W.
Washington 8, D. C.

Commander
Armed Services Technical Information Agency
ATTN: TIPCR (10)
Arlington Hall Station
Arlington 12, Virginia

Office of Techical Services
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Vertol Division, Boeing Airplane Co., Morton, Pa. FLIGHT TEST EVALUATION OF AN IMPROVED EXTERNAL CARGO SLING SYSTEM FOR H-34 HELICOPTERS. Report No. R-237, March, 1961, 50 pp-illus-tables. (Contract DA-44-177-TC-587) Proj. 9R89-02-015-14

Unclassified Report

Report describes flight test evaluation of an improved external cargo sling on an H-34 Helicopter. The improved cargo sling locates the effective point of cargo suspension nearer the helicopter C.G. for both pitch and roll thus reducing coupling moments resulting from motion of the cargo or the helicopter. Test results indicate substantial improvements in handling characteristics of the single rotor helicopter when using the double axis improved sling compared with the standard external cargo sling. Magnitude of improvement is comparable to that achieved on similar tests with a tandem rotor H-21 helicopter as reported in Vertol Report R-232.

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